Urban to Building Scale Modeling

Presented by: Robert L. Lee, Lawrence Livermore National Laboratory
(925) 422-1859, email: lee34@llnl.gov
LLNL Co-Investigators: R. Calhoun, S. T. Chan, D. E. Stevens
LANL Co-Investigators: W. S. Smith, J. Reisner, D. DeCroix, M. Brown

Objectives: Chem-bio releases in the atmosphere induce impacts over several spatial scales, both in the near field (close to the source) and out to the far field, potentially many kilometers downwind. While the most severe effects from typical chemical releases are confined to areas relatively close to the source, biological releases at small or moderate amounts can be lethal at much farther distances downstream and over a significantly larger area. The objective of the building-to-regional modeling program is to employ a multiscale approach in conjunction with a suite of computational models to address the various scales of dispersion scenarios. Flow and dispersion predictions are performed within "nested" domains with increasing spatial resolution from regional to intermediate/urban to building scales. The results from these models can be used for emergency planning of special events, vulnerability analyses, and the development of mitigation strategies. A longer term deliverable is to integrate this capability into a chem-bio emergency response system.

Recent Progress: Our modeling efforts this year were focused on developing and testing a nesting approach, performing model validation studies with wind tunnel data, and applying the models to the Salt Lake City (SLC) area to assist in pre-planning of the field experiments. We are testing a nesting approach in which the wind field prediction from a regional scale domain is used to drive the intermediate/urban scale domain which, in turn, drives the building scale simulation. Figure 1 depicts three nested domains superimposed on a 4 km resolution COAMPS forecast for the surface winds. Typical domain sizes and grid resolutions for the nests are: Regional – 100 km x 100 km, 4 km resolution; intermediate/urban – 10 km x 10 km, 50 m resolution; building – 1 km x 1 km, 5 m resolution. Preliminary calculations indicate that, for specific locations in which terrain effects are important (such as the greater Salt Lake City area), intermediate/urban scale dynamics are crucial in the capturing of terrain-induced mountain/valley flows that cannot be accurately resolved within large scale regional forecasts. Figure 2 depicts the nocturnal flows with surface cooling along the valleys and canyons (which are largely unresolved on the regional scale) east of the Salt Lake City area. Such terrain-induced wind fields are instrumental in the evolution of the prevailing southeast winds that are frequently observed in the Salt Lake City area.

We are continuing to evaluate and validate our CFD models using the CBNP-sponsored wind tunnel experiments conducted at the USEPA. Thus far, Reynolds-averaged (RAN) and LES-based flow results from the LLNL/FEM3MP and the LANL/HIGRAD models for the 2D block configuration have agreed well with measurements. Follow-up experiments for the 3D block configurations have recently been completed and modeling of that data has been initiated. Figure 3 shows the FEM3MP-generated RANS results of the horizontal flow vectors for the 7 x 7-block configuration. Model-data comparisons of vertical velocity profiles at selected stations show excellent agreement both upstream and downstream of the system of blocks and reasonable agreement for a station along the centerline of the first canyon. A new experiment around a 7 x 11 array of blocks was recently completed. The data obtained are of very high spatial resolution and include both mean and turbulence measurements. This set of unique data will provide a new resource for validating and improving the CFD models.

Model calculations have been initiated for dispersion scenarios within the Salt Lake City CBNP field observation area. Figure 4 depicts the dispersion pattern from a point source surface release south of the SLC downtown area as transported by a southeast wind. Note the impact of the tall office building on bifurcation of the plume downwind of the source. A number of dispersion scenarios have been generated with various source locations. The results show consistently that, depending on the wind direction, source location, buildings exhibit a significant impact on the dispersion patterns.

Future Outlook: We will continue to evaluate and validate the CFD models with wind tunnel measurements as dispersion data become available in the next quarter. In particular we will focus on comparing the model results with the CBNP-sponsored dispersion experiments from the NOAA/EPA wind tunnel and a series of LLNL on-site dispersion field experiments to be conducted this summer. Improved coupling of the nested domains will be achieved by assimilating time-dependent meteorological data from the boundaries of the domain and using the data to drive the respective flow predictions.

This work was performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under contract no. W-7405-ENG-48.

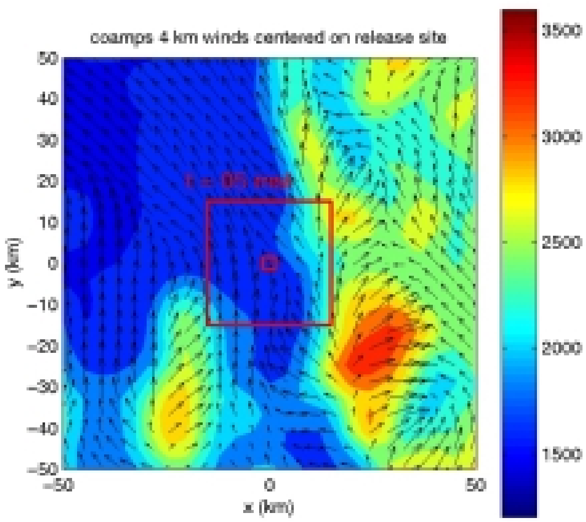

Figure 1: Regional Scale COAMPS surface winds superimposed on the SLC terrain. Also shown are two higher resolution nested domains.

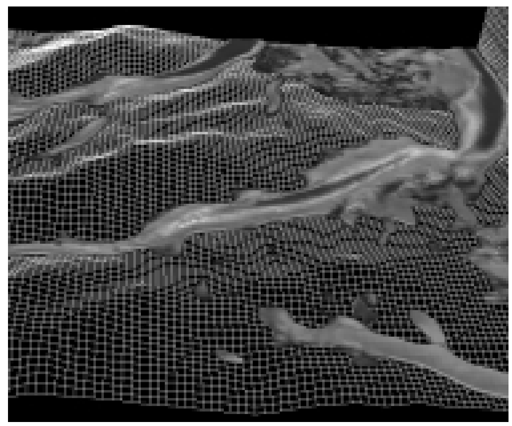

Figure 2: Intermediate/urban scale domain showing isosurfaces of perturbation temperature [-1.3 degress] shaded by wind speed.

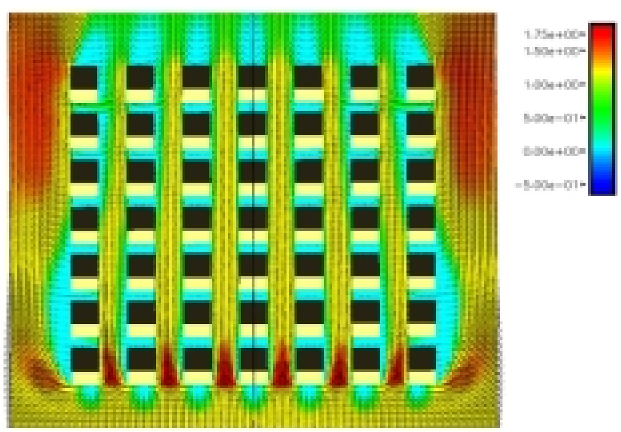

Figure 3: RANS results for the 7 x 7-multiblock simulation showing the flow speed and velocity vectors at the 1.5 cm plane.

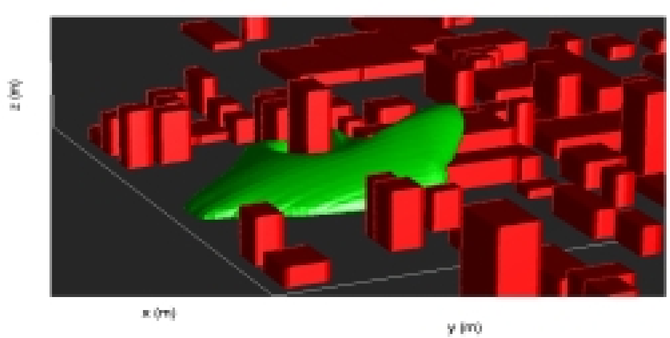

Figure 4: Dispersion pattern for a release south of the SLC downtown area